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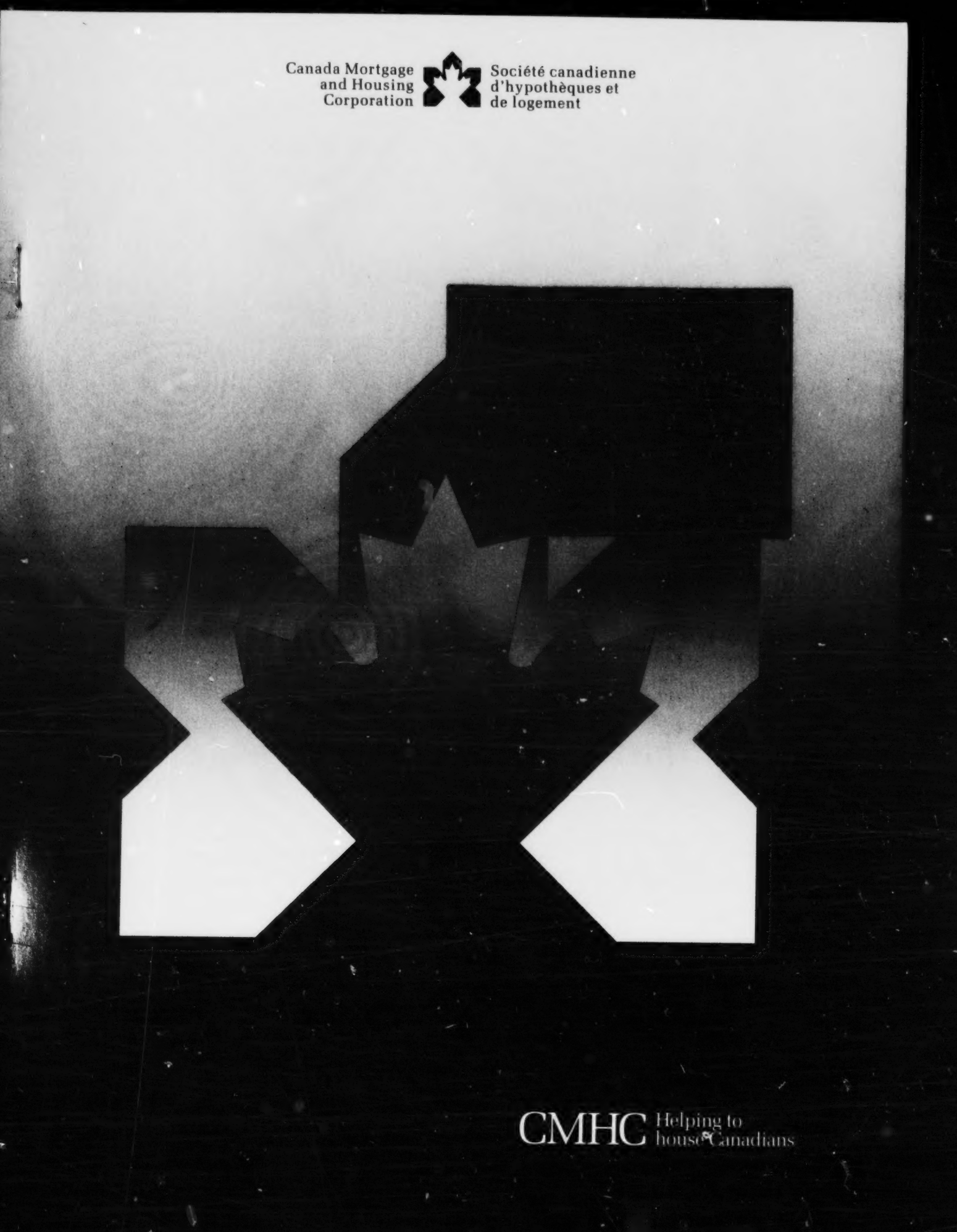

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PROPOSED RESEARCH STUDY FOR PLUMBING NOISE CONTROL IN CANADIAN BUILDINGS

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CLIENT REPORT

for

Canada Mortgage and Housing Corporation
National Office, 682 Montreal Road
Ottawa, Ontario K1A 0P7

Proposed Research Study for Plumbing Noise Control in Canadian Buildings

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EXECUTIVE SUMMARY

A review of the available literature on plumbing noise in buildings revealed that no work of any significance has been done in this field in North America; the major contributors to the literature are from France and Germany.

A small amount of the information from Europe is useful in North American buildings, but many questions remain unanswered. Accordingly a series of controlled measurements are suggested in this report to provide some answers. The magnitude of the problem may require more work in the future.

To maintain some compatibility with European information, measurements should follow the measurement procedures in ISO 3822, *Laboratory tests on noise emission from appliances and equipment used in water supply installations.* ISO 3822 describes a reference hydraulic noise source called the installation noise standard, INS. Wherever possible it must be used for the above measurements. In some parts of the work, common taps will be used. In measurements of noise from waste pipes, it is the interaction of the water with the pipe that is the noise source.

Measurements must be made in the octave bands from 63 to 4000 hertz. This range may be extended and one-third octave band data may also be presented. A-weighted levels must also be calculated from the measured data as specified in ISO 3822.

The goal of the research study described here is to determine in a controlled situation the effects of a number of factors on the noise level from plumbing systems. These factors include the use of copper and plastic pipe of different diameter, the effect of system pressure, the effects of resilient mounting for pipes, the effects of resilient mounting for drywall, the effects of sound absorbing material in wall cavities, and the differences between steel and wood studs. The investigations are to be made for basic wood and steel stud systems. Since typical noise levels from domestic North American taps are largely unknown, part of the study should include measurement of noise from domestic taps. To provide comparison with European data, these tests should be done using a masonry wall.

Noise levels from waste pipes should be investigated at the same time as the supply pipes. Many of the same noise reduction techniques are applicable to them too. Measurements of the sound radiated from free standing waste pipes should be included in the program.

> *The background noise level in the receiving room should be at least 10 dB below the level produced by the appliance under test. This in general will require a very quiet room with a background noise level of less than 30 dBA. For testing very quiet systems, a background even less than 20 dBA may be needed. Because of this requirement, it is likely that this work can be done only in an acoustics laboratory.*

This set of measurements will answer many questions about how best to deal with plumbing noise. Some future work may need to be done after this project is completed, but it can only be planned properly after these preliminary experiments are complete. Demonstration projects where complete plumbing installations are acoustically correct may then be more useful than laboratory measurements on isolated components. The demonstration projects could be constructed in a building or a laboratory mock-up.

INTRODUCTION

Recommendations made for control of plumbing noise in buildings contain almost no quantitative or practical information that relates directly to the North American style of lightweight building. In an extensive search of relevant acoustical literature, French and German papers dominated the list of practical papers. Even those papers, however, tend to focus on a fairly narrow issue: methods for measuring and reducing the noise from devices such as taps and appliances.

Some of the information developed in Europe is applicable to those North American buildings that use solid concrete construction. A summary of this and more information on the European approach to the problem of plumbing noise can be found later in the report. Even where the North American construction resembles the European, however, there is no available information about the levels of noise generated by North American plumbing appliances.

In North American acoustical literature, if plumbing noise is addressed at all, it is usually recommended that all pipes and appliances be isolated from the structure of the building using some resilient material. The recommendations are given in general terms and there is no information on how much noise reduction one can expect if the recommendations are followed. There are, therefore, many unanswered questions especially for lightweight construction. For example:

> How much does sound absorbing material in walls or in pipe chases help to reduce radiated sound?
>
> How much does mounting drywall on resilient channels help?
>
> Which resilient material is best around pipes?
>
> Is there a difference between copper and plastic pipes?
>
> If resilient mounts have been omitted, will it help to insert sound absorbing material in the wall cavities?
>
> What noise reduction in dBA can I expect if I do all or only some of these things?
>
> Are steel studs better than wood studs?

The answers to these and other questions are not to be found in the published literature. The experimental program of measurements described here should provide quantitative answers.

DESCRIPTION OF RESEARCH WORK

The general intent of the work described here is to determine in a controlled environment, the effectiveness of commonly prescribed techniques for control of plumbing noise in buildings. The project deals primarily with lightweight wood and metal stud construction.

To provide a link and reference to European work, measurements should follow as far as possible the measurement procedures and physical requirements of ISO 3822, *Laboratory tests on noise emission from appliances and equipment used in water supply installations*. A major difference is that the radiating wall will not be a 150 mm concrete wall but will change as the experiment progresses. Since the type of wall used will change, the area specified in ISO 3822 is not relevant for this study. The standard hydraulic noise source described in ISO 3822, the installation noise standard (INS), must be used to generate noise in the system. Measurements must be made in the octave bands from 63 to 4000 Hz. This range may be extended and one-third octave band data may be presented as well. A-weighted levels must be calculated from the measured data as specified in ISO 3822.

When the INS is used to test supply pipes and systems, measurements must cover the range of supply pressure from 0.1 to 0.5 MPa inclusive as suggested in ISO 3822. At least four values of pressure should be used. Flow rate must also be measured when supply systems are being tested. When taps are being tested, sound levels should also be obtained as a function of flow rate by adjusting the valve setting at constant pressure, for example 0.3 MPa.

> *The background noise level in the receiving room should be at least 10 dB below the level produced by the appliance under test. This in general will require a very quiet room with a background noise level of less than 30 dBA, or for testing very quiet systems, about 20 dBA. Because of this requirement, it is likely that this work can be done only in an acoustical laboratory.*

Figure 1 shows a sketch of the basic test rig. The details of the INS are copied from ISO 3822 in Figure 2. Noise from the INS transmits through the piping systems and radiates from the test wall into the reverberant room. The object of the experiments is to measure the sound level in the room due to radiation from the wall surface for several wall and plumbing systems.

A. Noise From Supply Pipes and Appliances

This set of measurements is intended to show the effects of changes made to the supply plumbing system and the methods used to support it in the building structure. The structures should be typical of those used in North American lightweight construction unless otherwise specified. Noise levels in a receiving room are measured in accordance with the requirements outlined above and the following factors are studied.

1) *Copper and plastic pipe*

   An earlier French study gives evidence that plastic pipes are somewhat less noisy than copper pipes. Some of the low flow velocity measurements were, however, contaminated to some extent by background noise. New measurements will show the differences for North American lightweight construction.

2) *Different pipe diameters*

   Increasing pipe diameter reduces water velocity for a given volumetric flow rate. Whether this will result in significant reductions in noise in a complete system, needs to be verified. Measurements should be made using pipe diameters of 12 mm and 25 mm.

3) *Different system pressures*

   Increasing system pressure leads tc increased noise. The importance of this with lightweight construction needs to be measured; hence the requirement to measure over the range from 0.1 to 0.5 MPa.

4) *Standard, cork, felt, and rubber wrappings for pipe isolation for surface mounted pipe and pipes passing through studs*

   The effect of resiliently mounting pipes on the structure needs to be measured for different types of lightweight construction and different types of resilient materials. For rubber and similar materials the durometer hardness should be measured and reported. If commercial resilient products are available in North America, some of these should also be tested.

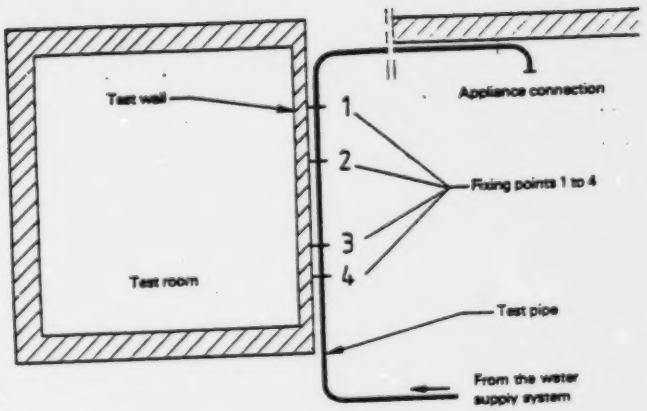


Figure 1: Basic test rig for measurements according to ISO 3822

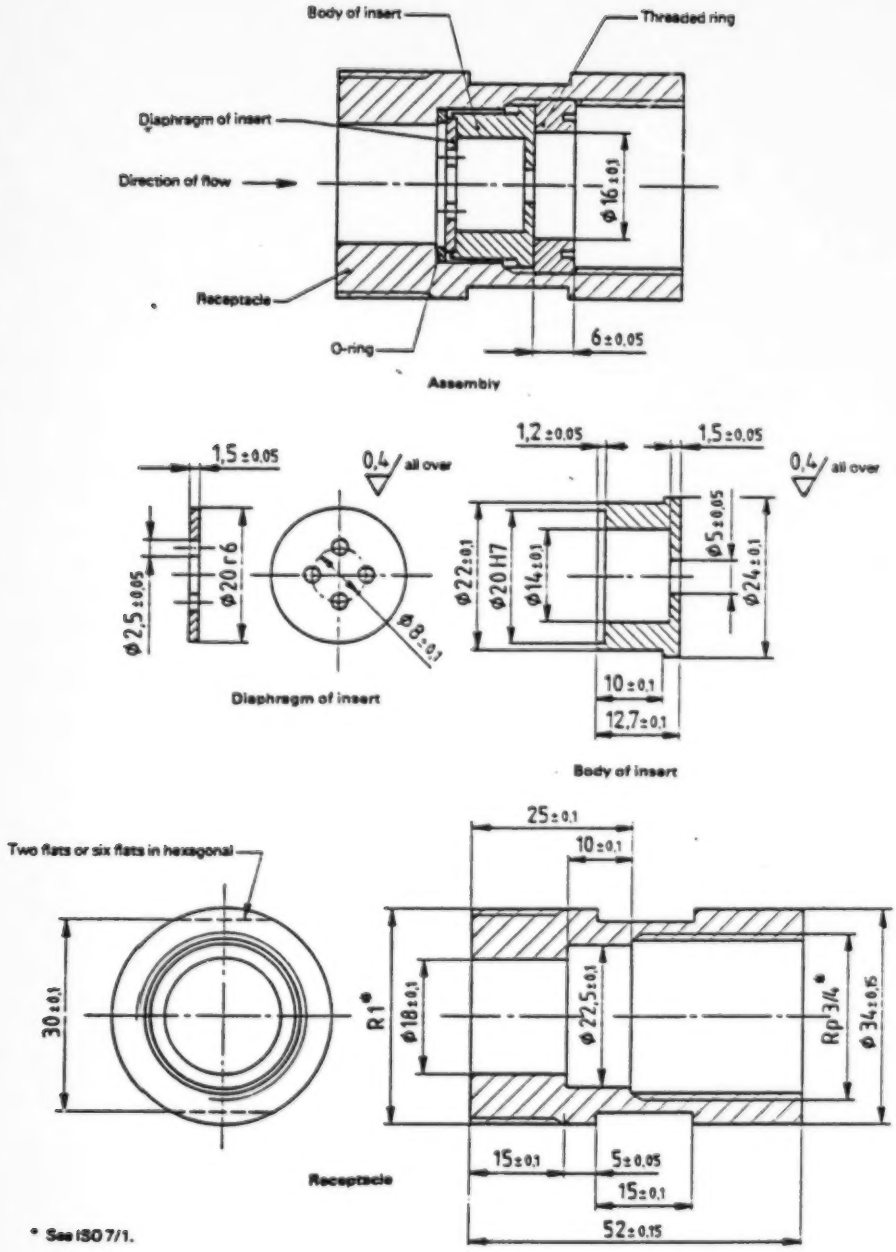


Figure 2: The installation noise standard (INS)

5) *Resilient mounting of drywall with and without sound absorbing material in the cavity, with and without resiliently mounted pipes*

As protection against installation errors, alternative approaches to plumbing noise control should be evaluated. One such approach is the use of resiliently supported drywall on both sides of a bathroom wall. Even if the plumbing system is incorrectly rigidly attached at some point in the structure, the use of resiliently supported drywall might help to offset such errors.

6) *Sound absorbing material in cavity without resilient mounting of drywall or pipes.*

In an existing installation that is excessively noisy, sound absorbing material might be blown into the wall cavity in hopes of improvement. The effectiveness of this technique, if any, should be evaluated.

7) *Steel studs with and without sound absorbing material in the cavity.*

There may be differences between these two common types of stud systems. Some of the measurements should be repeated with steel studs to find what the differences are.

8) *Different domestic taps*

There is no legislation in North America requiring that plumbing appliances be classified as to the noise they generate. There are no regulations about acceptable levels of plumbing noise either. Some information is needed about the level of noise from typical taps to estimate the size of the plumbing noise problem and to compare with European tap data. This measurement set should be done with a masonry wall with a mass per unit area between 100 and 250 kg/m^2 as recommended in ISO 3822. Since this is a research project, however, some details, such as wall area, will not be significant as long as they are fairly typical.

B. Waste Pipes

The noise of flushing toilets and draining bathtubs is a common source of annoyance and sometimes embarrassment. Quiet toilets are available but the noise of water falling through the waste pipes can still be annoyingly loud. Since the physical mechanisms are different from those with supply pipes, a separate set of experiments is necessary. The INS source is not used but average sound levels should be measured as before. The intent is to investigate the same factors that are investigated for supply pipes. Experiments should determine sound levels for

1) *A free-standing waste pipe*

The level of noise from a waste pipe needs to be known so pipe chases and walls can be properly designed to reduce noise from them.

2) *Standard, cork, felt, and rubber isolation for waste pipes with wood studs*

Attachment methods should give a good simulation of field practice.

3) *Standard, cork, felt, and rubber pipe isolation with steel studs.*

A repeat of the experiments in set 2 but with steel studs.

Separate pipe chases are recommended for critical situations. How well they work and whether they have any influence on airborne sound transmission loss will depend on the details of the design of the wall and pipe chase. The experiments to measure the level of noise from free-standing waste pipes will provide the necessary information for design of a pipe chase. Existing knowledge about the design of walls for good sound transmission loss should allow the design of pipe chases that do not reduce privacy.

With careful design of the experimental program, the test assemblies can be constructed to include both supply and waste pipes. This reduces construction costs and should speed testing.

CONCLUSION

The technical data obtained from this research study, existing literature on plumbing noise and architectural acoustics should allow the preparation of better, practical, non-expert guides to the control of plumbing noise in Canada.

The nature of research work is such that it often raises more questions than it answers. Some questions are not dealt with in the proposed work above. The practicality of some of the proposed details for control of plumbing noise can not be addressed until data are available from this study. At that time more complicated, more realistic installations will probably need to be tested. These mock-ups could be constructed in a laboratory or in a building.

APPENDIX A

Summary of Factors Influencing the Level of Plumbing Noise

The major causes of noise in a plumbing system are:

a) *Turbulent and cavitating flow caused by obstructions in the pipes, such as elbows, taps, valves, etc.*
b) *Excessively high system pressure*
c) *Excessively high water velocity*
d) *The impact of water in baths, basins and sinks, and impact on the walls of waste pipes*
e) *Gurgling sounds due to sucking of air through drain holes during emptying of sinks, baths, etc.*

a) *Turbulence*

The noise level generated by the flow of fluid within pipes depends on what type of flow takes place. At low speed, flow is laminar and there is very little noise generated. When flow becomes turbulent the noise generated increases strongly. In domestic systems flow is invariably turbulent because of the velocity exceeds a critical limit.

Roughness within the pipes can also generate turbulent flow. Lumps of solder, rough pipe ends and other protrusions in the pipe can increase noise levels. In practice, however, there is little that can be done to control this aspect of the plumbing installation.

b) *Pressure*

Noise generated in the plumbing system increases rapidly with increasing pressure; increasing pressure means increasing velocity. If pressure is too high, taps are only opened slightly to get the required flow rate. The small restriction leads to increased turbulence, possibly cavitation and greater noise. If the supply pressure doubles, the noise increase can be around 6 to 9 dBA. To reduce this contribution to the noise, system pressure should be kept below 0.3 MPa as far as possible. Pressure regulators will do this but quiet ones must be chosen for some will generate significant amounts of noise.

c) *Pipe diameter*

Increasing the diameter of the supply pipes reduces the water velocity for a given delivery in litre/second. A lower velocity reduces the noise generated in the system. Where large volumetric flow rates are required, such as for a bath, large diameter pipes should be used.

Some typical values of volumetric flow rate are:

filling a glass	.06 - 0.07 l/s
hand washing under tap	0.09 l/s
filling a pot	0.15 l/s
filling a bucket	0.3 l/s

d) *Effects of bends, tees etc.*

Sharp bends, tee junctions and sudden changes of cross-section are all potential causes of noise in a plumbing system. Bends should be gradual and the number of tees should be reduced to a minimum. Changes in cross-section should be made gradually with a cone angle of about 15 degrees.

e) *Effect of pipe material*

Experiments made in the Acoustics Section of the French Institute of Building and Public Works Laboratories around 1960 (Marseille; 1964, 1965) showed the effects of changing the supply pipe material. The sound emission from freely suspended pipes was measured for several flow velocities. The pipe materials used were copper, steel, lead, plastic and plastic covered copper. (The latter is a type of pipe that was used and may still be used in Germany.) Of these materials, only copper and plastic are in common use in North America. The results for these two materials are given in Table A1. Measurements were made at lower flow velocities than those shown in the tables. The author points out, however, that at the lower velocities the noise generated by the plumbing was too close to the background noise in the room. Those results are not presented here to avoid confusion. The same pipes were then attached to three types of solid wall: 3.5 and 5 cm brick and 14 cm concrete. The results for these conditions are shown in Table A2.

TABLE A1

Sound Emission From Freely Suspended Piping (dBA)

Water Velocity m/s	Type of Pipe	
	Copper	Plastic
3.4	46	41
5.2	46	41

TABLE A2

Sound Emission From Piping Fixed to Walls With Steel Clips (dBA)

	Copper Pipe			*Plastic Pipe*		
Velocity	Wall Thickness (cm)					
m/s	*3.5*	*5*	*14*	*3.5*	*5*	*14*
3.40	51	50	47	43	47	40
5.20	54	53	48	40	45	39

Although there are some anomalies, the data show that, in domestic systems where pipe sizes are relatively small, attaching pipes to the structure can greatly increase noise levels in adjacent spaces. Structural elements radiate sound far more efficiently. This is why it is important to isolate the piping.

Experiments to look at the effects of different types of clips for attaching the pipes were carried out. Two types of clips were used: steel and plastic. The results are reproduced in Tables A3 and show the advantage of the plastic clips. Unfortunately, the report gives no physical description of the plastic clips. One puzzling result was obtained in a short test when steel clips with a rubber sleeve were compared with the plastic clips; the plastic clips were slightly better (Table A4). This result needs further investigation.

TABLE A3

Comparative Sound Emissions From Piping Fixed to Walls With Steel Clips and Plastic Clips (dBA)

Copper

	Wall Thickness (cm)					
	3.5		5		14	
Velocity m/s	*Clip*		*Clip*		*Clip*	
	Steel	*Plastic*	*Steel*	*Plastic*	*Steel*	*Plastic*
3.40	51	47	50	48	47	46
5.20	54	47	53	48	48	46

Plastic

	Wall Thickness (cm)			
	5		14	
Velocity m/s	*Clip*		*Clip*	
	Steel	*Plastic*	*Steel*	*Plastic*
3.80	47	44	40	--
5.70	45	41	39	--

TABLE A4

Sound Emission From Steel Pipe (dBA) With Steel Clips With Rubber Sleeve, and Plastic Clips

Velocity m/s	*Plastic Clips*	*Rubber-Sleeved Steel Clips*
3.4	36	40
5.2	37	39

Of the wall constructions used in the experiments, only the 14 cm concrete is relevant to the North American building industry. No information about stud walls was found. Close examination of the original research papers shows that there are some anomalies. In part these are due to the inadequate instrumentation available almost 30 years ago. Additionally, the structures are not typical of Canada. This is why repeat measurements are recommended.

Flexible Connections

Vibration generated by taps and other apparatus is transmitted to the walls of the pipes as well as propagating in the water itself. Vibrations in the pipe walls attenuate with distance very slowly - about 1/4 dB per metre. If a flexible section, metallic or rubber, is introduced into a run of pipe it will reduce the level of vibration in the pipe walls immediately downstream. However, the vibration in the fluid is not affected by this and a few metres further downstream the level of vibration in the pipe wall is restored almost to the level upstream from the resilient element. Where flexible connections are used, they need to be installed about every 6 m along the pipe to ensure that the pipe wall vibration level stays low.

While flexible connectors are useful in controlling plumbing noise, there could be health risks from the materials used, or these elements might have a much shorter lifespan than conventional pipe.

Noise From Taps

Inside taps, as in all hydraulic equipment, the acoustical phenomena are particularly complex. When water encounters obstacles, reductions in pipe cross-section etc, turbulent flow occurs and perhaps even cavitation. The turbulent motion results in vibration which in turn causes sound radiation.

Cavitation

Cavitation occurs in water when, due to a constriction, the water velocity increases and the pressure decreases to the point where bubbles of vapor are formed. Downstream from the constriction the velocity decreases and the pressure increases. The vapor bubbles then collapse suddenly causing shock waves and noise.

Water Hammer

The sudden bang known as water hammer occurs when steady flow in a plumbing system is abruptly stopped, for example by closing a quick action valve. With the fluid in motion throughout the whole piping system the momentum, even at low flow velocities, can be great. Since most liquids are essentially incompressible, the sudden cessation of flow results in an extremely sharp pressure rise at the point of shut-off, and the entire system vibrates. The shock wave can be reflected back-and-forth several times through the system until the energy is finally dissipated.

APPENDIX B

Test and Rating Procedures, ISO and Europe

In Europe the major part of the testing and labelling effort is directed to the noise from taps and appliances. These are tested according to the relevant national standard and given a number. The German and French standards for this are virtually identical with each other and the ISO standard. The noise from a tap is compared with that from a reference hydraulic noise source and a rating D_S is assigned. This number is the difference between the A-weighted levels generated by the standard source, Ls, and the tap under test, L.

$$D_s = L_s - L \qquad \text{(dBA)} \qquad \text{(B1)}$$

The better the product, the greater the number. In France, a class I tap has a D_s greater than 25 dBA and a class II tap has $15 < D_s < 25$ dBA. Taps with $D_s < 15$ dBA are not given a rating.

This approach is in accord with the philosophy that the best place to reduce noise is at the source.

Prediction of Noise in European Buildings

On the basis of many measurements of the noise generated in European buildings, it is possible to predict the level of noise generated by a tap for a variety of installation conditions and supply pressures.

Figure B1 shows the average noise generated by the INS, the reference source, for transmission in the horizontal plane. Figure B2 is for the vertical plane. Note that configuration 16 in Figure B2 is for a path that is diagonal in both vertical and horizontal planes.

With this information a designer can predict the noise generated by a tap he has already chosen, or select a tap that will meet the maximum noise level requirements of the building regulations. In France the maximum permitted noise levels are 35 dBA for individual fixtures and 30 dBA for collective apparatus such as elevators and common plumbing supplies or waste pipes.

For example, suppose a sink and its supply pipes are attached to 150 mm thick reinforced concrete wall. On the other side of the wall is the living room of the neighboring apartment. What is the level of noise there if the tap in the sink has a D_s of 16 dBA and the supply pressure is 0.3 MPa?

The first step in solving this problem is to identify the appropriate physical layout from the lower part of the figures. In this case we are dealing with transmission in the horizontal plane so Figure B1 is the appropriate choice. The physical layout corresponds to drawing number 5 in Figure B1. The boxed numbers in each figure identify the curve to be used with each physical layout. The line for case 5 crosses the 0.3 MPa vertical line at a level of 45 dBA. Substituting these values into equation B1 gives L = 29 dBA. This would satisfy the French regulations.

The prediction scheme described here suits French construction but the light masonry partitions in the figures are not typical of those found in North America. Thus, very little of this information can be used on this continent.

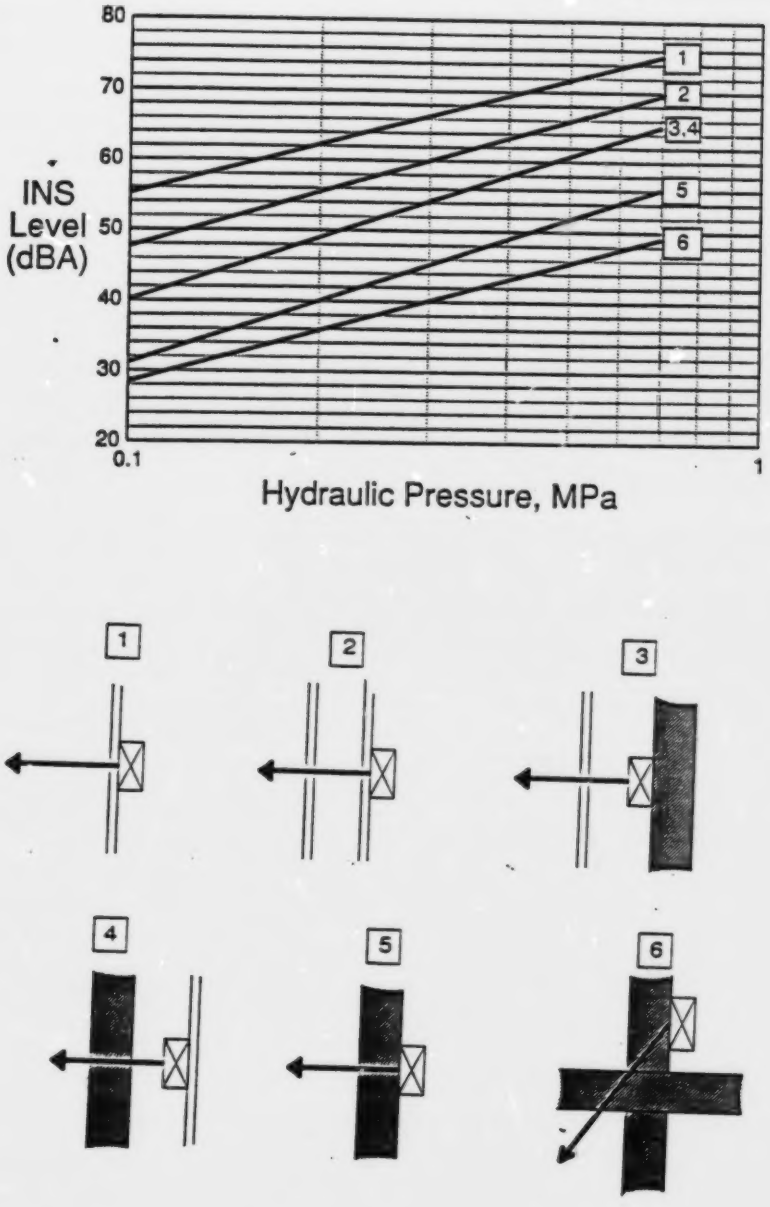
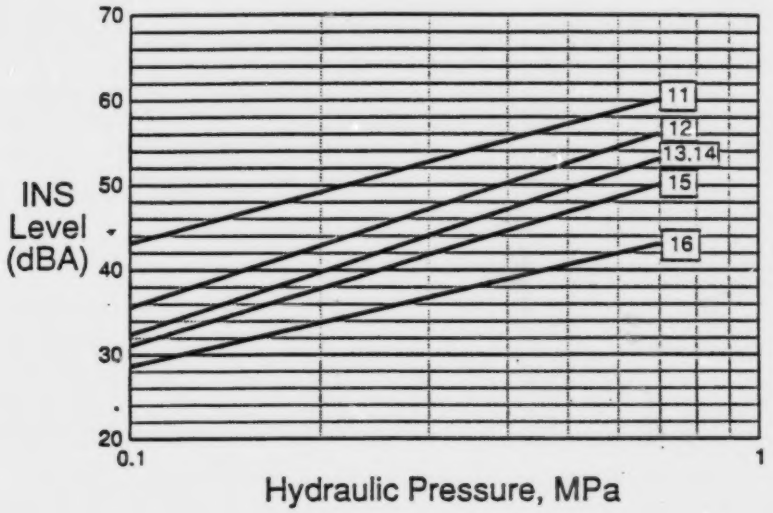
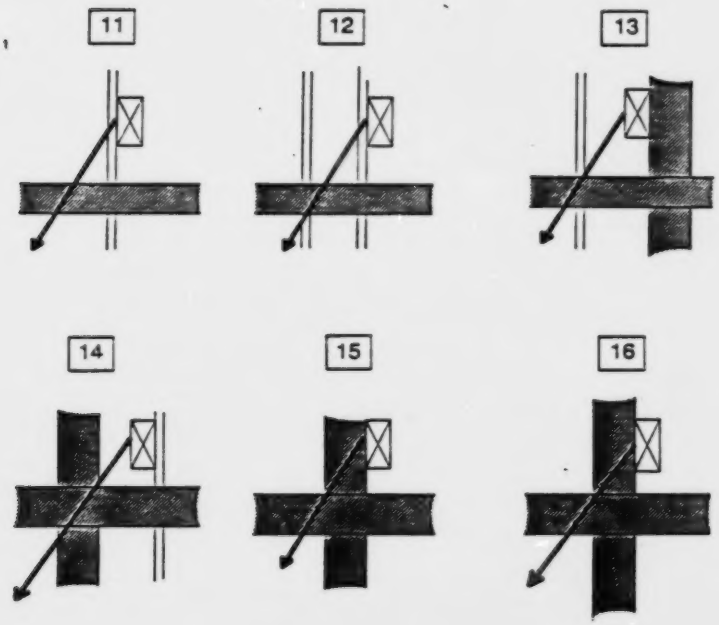


Figure B1: A-weighted noise level generated in other rooms on the same horizontal level by the INS source. The rectangular box represents the INS, the grey bars are concrete party walls, and the narrow parallel lines are partitions within an apartment.





VERTICAL SECTIONS

Figure B2: A-weighted noise level generated in other rooms in the same vertical plane as the INS source. The rectangular box represents the INS, the grey bars are concrete party walls, and the narrow parallel lines are partitions within an apartment. Note that in configuration 16 the receiving room is diagonally removed from the source in both horizontal and vertical planes.

APPENDIX C

Recommended Procedures for Quiet Plumbing Installations

While there are many questions yet to be answered about control of plumbing noise, the literature survey provided an opportunity to review what is known. This appendix summarizes that knowledge. Much of it has appeared elsewhere but not always together and not always in English. The data from the research study, when added to this information, will provide an excellent guide to control of plumbing noise in Canadian homes.

Anti-Vibration Mounting

Noise generated by a plumbing system may be reduced by mounting pipes and equipment resiliently. This isolates them from walls and partitions which are the major radiators of sound. This task is made more difficult because there are few anti-vibration mounts sold specifically for this purpose. Also, for this isolation to be effective, it must be complete. This demands careful workmanship with absolutely no solid contact between the structure and the plumbing. Such careful workmanship is hard to obtain.

The philosophy held by some Europeans is that rather than trying to get high quality workmanship, it is better to test and rate plumbing fixtures for the noise that they generate and insist on the manufacture and use of quiet devices. Architects can then specify these quiet fixtures and meet the noise criteria for their buildings. Others still seem willing to try for higher standards and recommend anti-vibration mountings as outlined above.

Sketches showing recommended procedures for isolating the plumbing components from the building may be found in the references listed at the end of this report. A selection from the references is repeated here for convenience. Resilient mounting is recommended for connecting pipes to walls, and resilient isolators when pipes pass through walls (See Figure C1 for examples). The complexity of the installation depends to some extent on the complexity of the structure the pipe is passing through. It has been suggested that the use of such resilient isolators helps to reduce the creaking or cracking sounds that occur when hot water pipes expand and contract.

Sinks, tubs and showers should also be isolated from the structure using resilient mounts. These installations become very complex in the case of toilets, showers and baths for example. (See Figures C2 and C3).

The requirement for careful workmanship might be eased to some extent by over-designing, a sort of "belt and suspenders" approach. In principle, if the plumbing system is correctly isolated, noise is reduced; in practice, errors occur during installation. If all the wall surfaces in a bathroom are mounted on resilient channels, no matter what other construction breaks exist already, this might help ensure good noise reduction. Even if pipes and appliances do touch the structure, the resilient channels should reduce the noise radiated from the drywall.

Only one comment about the effectiveness of vibration isolation was found in the literature review. Noise reductions of about 10 dBA resulted when a bathroom installation in a laboratory was redone correctly. Once again the noise reduction will depend on the type of construction among other factors.

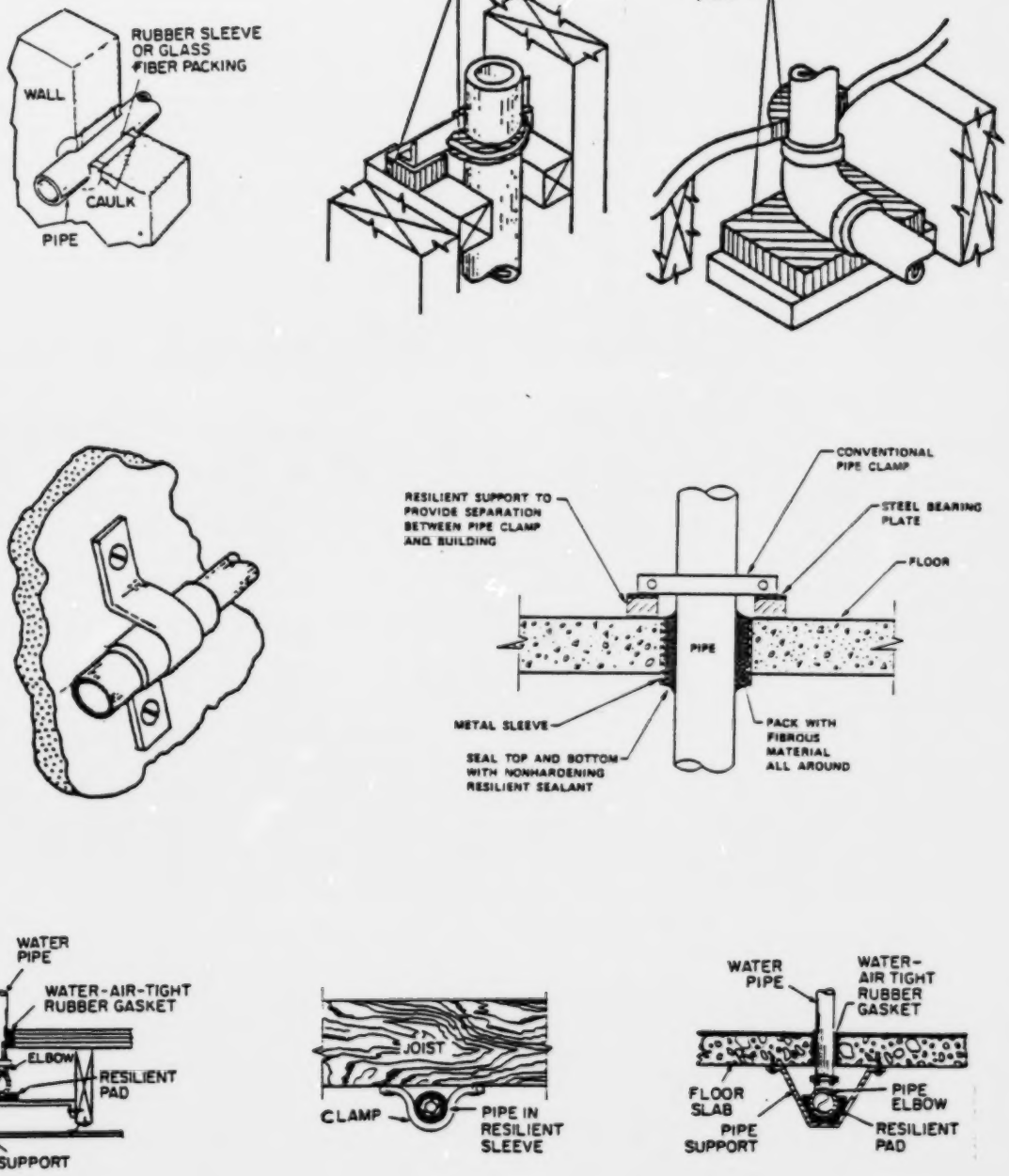
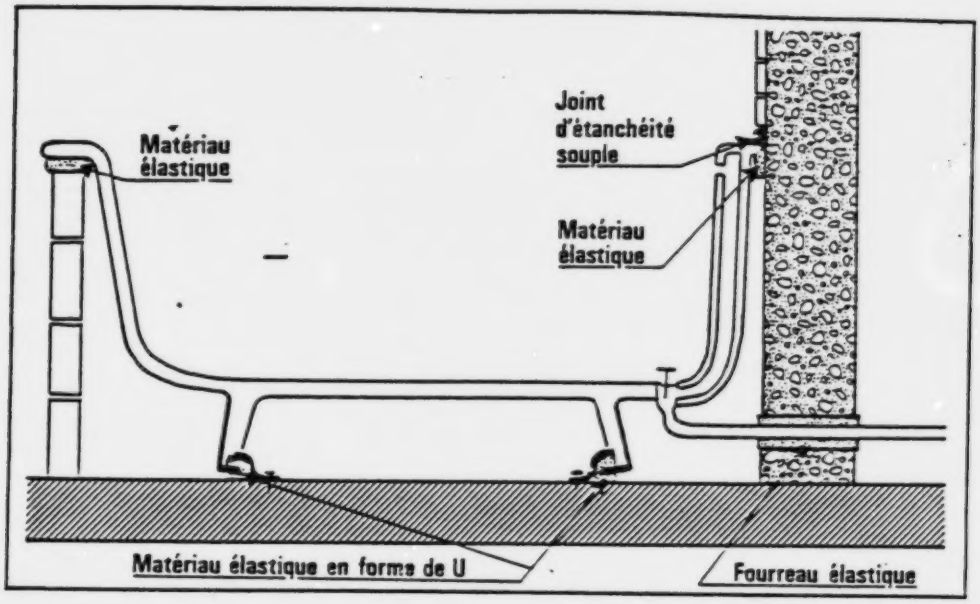


Figure C1: Examples of methods used to isolate pipes from the building structure. Correctly placed resilient materials reduce the transmission of vibration and noise without loss of support.



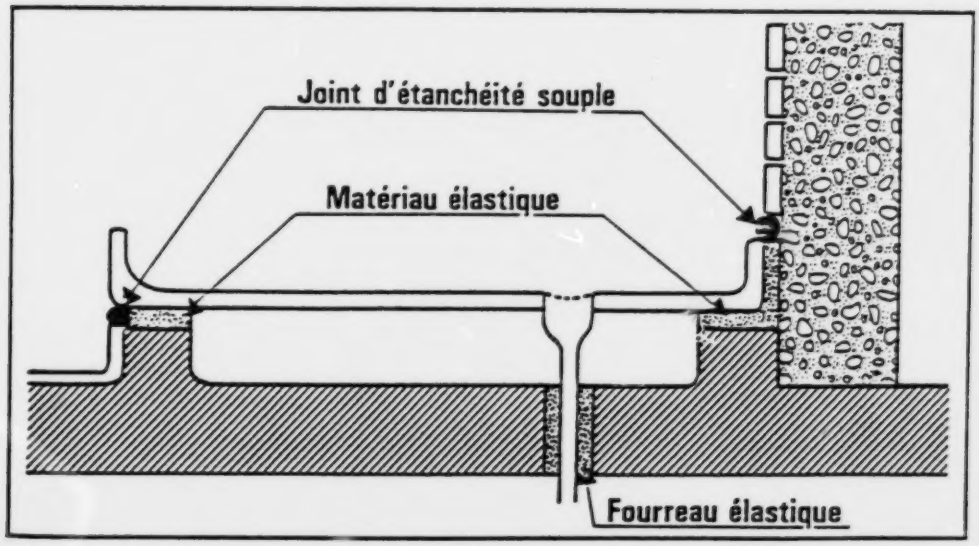


Figure C2: Examples of vibration isolation of a bath and a shower.

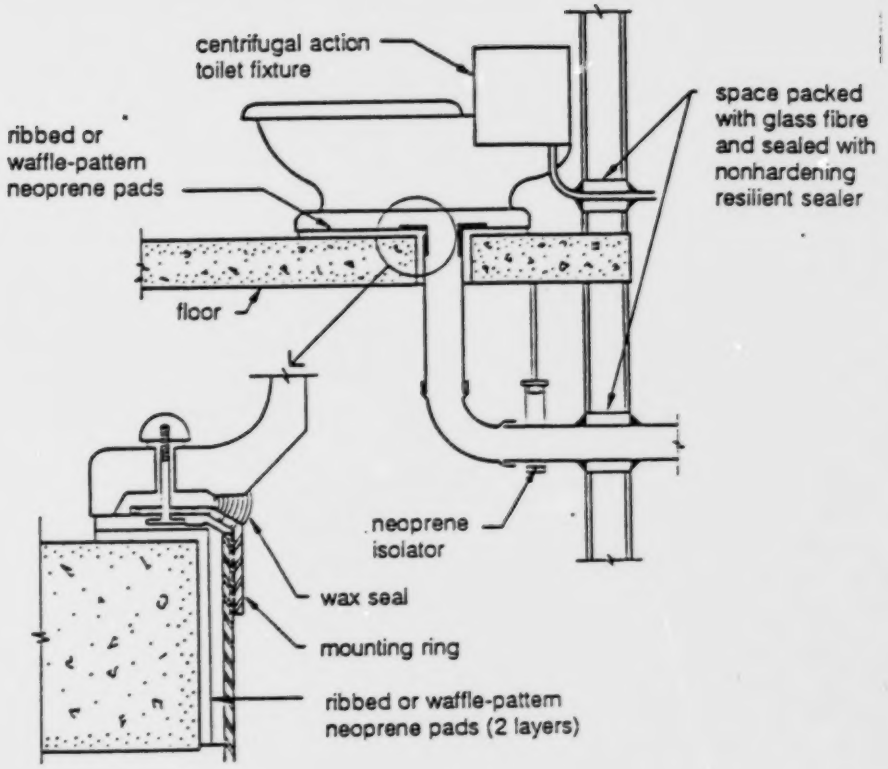


Figure C3: Suggested vibration isolation for a toilet.

Supply Pressure and Velocity

As pointed out earlier, supply pressure and velocity influence the level of noise generated. Experience in Europe has shown that a velocity of around 2 m/s is quite acceptable. To keep velocities low, large diameter pipes should help but the noise may still be controlled by taps and valves. The supply pressure in a building should be kept around 0.3 MPa. Branch lines serving individual apartments should be less than this, about 0.2 to 0.25 MPa, In high rise buildings with high-pressure main supply lines and daily fluctuations in demand, meeting these limits will certainly require the use of regulators. These should of course be quiet devices.

To keep velocity down to the recommended limit requires the use of large pipe diameters. Large diameter, 25 mm, pipes should be used for main supply lines and for devices such as baths. For washbasins, the volumetric flow rates are low enough that regular 13 mm pipe is acceptable. For showers and kitchen sinks, 18 mm is needed. The common supply lines in a high rise present special design problems that need careful professional analysis.

Selection of Equipment

It is always most effective to reduce noise at the source. In plumbing this is done by selecting quiet components, taps for example. Siphon jet or centrifugal action toilets are considerably less noisy than the conventional models. The noise generated by a bathtub or a sink can be reduced during filling by having the water strike an inclined surface immediately after it leaves the tap instead of falling a few feet to bang on the bottom of the tub. With North American tubs not designed in this way, there is little the purchaser can do. Noise generated by water pounding on a surface can be reduced somewhat, however, by applying layers of damping compound to the back side of the tub. The cost of such a treatment on a building site is likely to be prohibitive and not practical.

It would be nice if cost were a guide to the level of noise generated by an appliance. In North America there is no information but one European author commented that there appears to be little relationship between noise generated and cost. This suggests that manufacturing quieter plumbing components is not necessarily more expensive.

Noise during emptying of a tub or a sink is generated when air is sucked through the overflow hole causing a loud gurgling sound. There can also be loud sucking and gurgling sounds from the trap at the end of the emptying cycle. To reduce these two types of sound the overflow outlet should be as low as possible in the drain, the diameter of the drain should be greater than that of the pipe leading to the trap. The drainpipe from the trap should also have a larger diameter than the trap and a gentle slope so the drain pipe is not completely full. (Figure C4)

Control of Water Hammer

One simple method of controlling water hammer is to introduce a short vertical stub of pipe filled with air close to the valve. The air trapped in the stub acts as a cushion to absorb and damp the shock wave produced by the sudden closure of the tap. Figure C5 shows the principle and a sample installation near a washbasin. These devices are particularly useful near clothes and dishwashing machines which commonly have fast-acting valves. While this remedy is effective and simple, over time the air trapped in the stub dissolves in the water and the system must be drained to allow the stubs to fill again with air. Valves close to the stubs could be included to allow local drainage, but this would increase system cost. More complicated devices could be used, incorporating rubber diaphragms for example, but could be prone to failure after prolonged use. In long runs of pipe, air stubs can be introduced at several places along the pipe.

Waste Pipe Layout - Avoidance of Impacts

When waste water enters a junction it should do so at an angle such that the change in direction is gradual. This reduces noise generated because of the heavy impacts. Figure C6 shows two examples of poor installations and two suggested solutions.

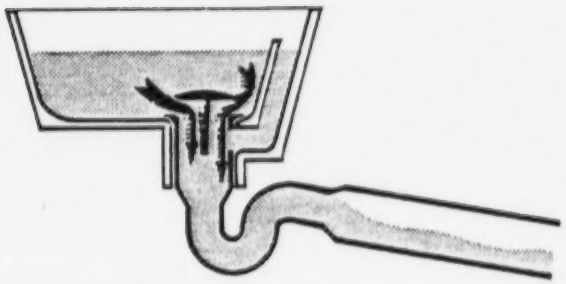


Figure C4: Suggested design for a sink showing different diameters of trap, drain and waste pipes.

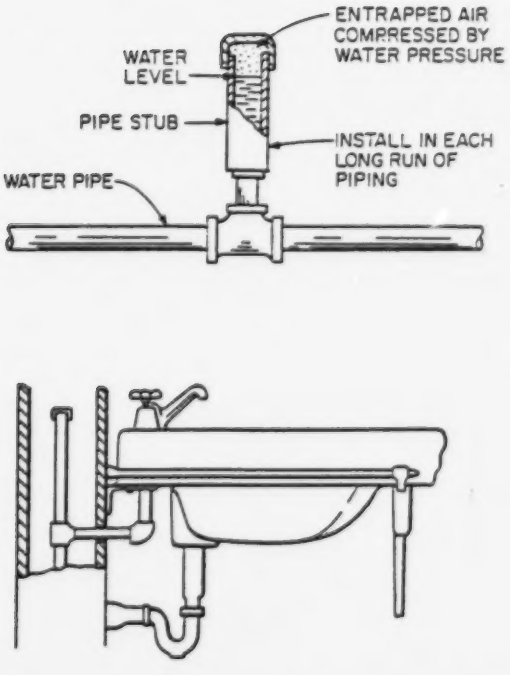


Figure C5: Sketch of air-filled stub for absorbing water hammer shock. The lower sketch shows an installation close to a sink. They should also be installed close to other appliances such as dish and clothes washing machines.

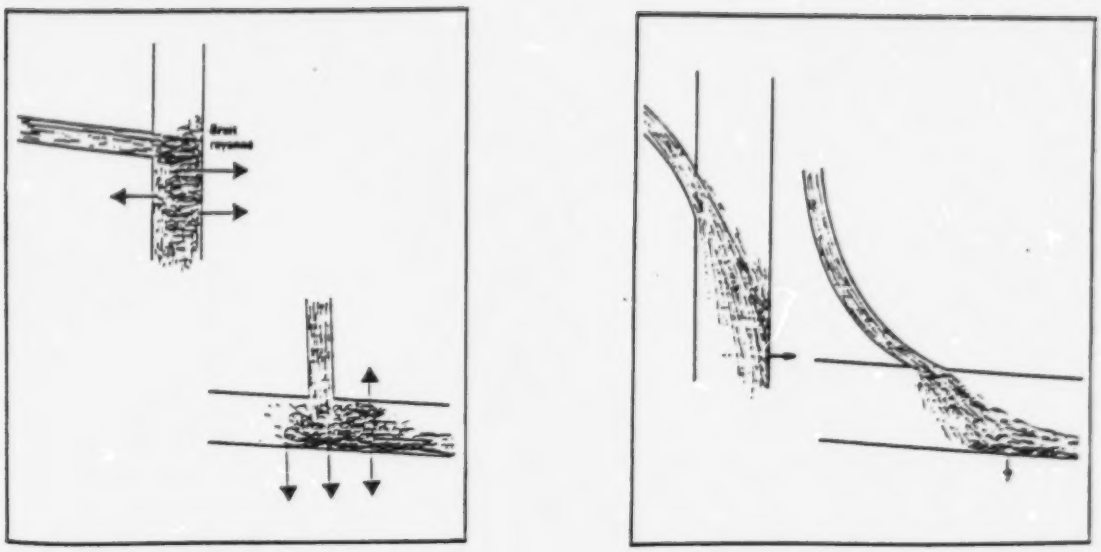


Figure C6: On the left two examples of poorly arranged waste pipes where the impact of the waste water will cause vibration and noise. The alternatives on the right are quieter.

APPENDIX D

Bibliography

This bibliography references material that was found to be useful for this report. There are other sources of information on noise in pipe systems but they do not deal with domestic systems or repeat much of the information from these references. As in other areas of knowledge, there is a great deal of repetition of ideas and information. The essence of the information in these references has been presented in this report.

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